SYNTHESIS REPORT

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DESIGN METHODOLOGY FOR MICROENGINEERED FLUID DEVICES

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PROJECT CO-ORDINATOR: GEC-Marconi Materials Technology

PARTNERS:
Siemens
3T
Fraunhofer Institute for Solid State Technology
Heriot-Watt University

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1 ABSTRACT

in the form of the inkjet printer head. Microengineered fluid devices provide one of the strongest examples of the practicality of Microengineering concepts. tools and techniques outside the field of Microelectronics. This project on the Design Methodology for Microengineered Fluid devices focused on providing general approaches for the further exploitation of Microengineered fluid devices across a broader range of applications encompassing both chemical microanalysis tools and surgical power transducers. The general' approach taken was to develop basic interfacing methods enabling the integration of individual microengineered components into complete fluid microsystems incorporating both fluid and electronic interfaces. The primary objective was thus to demonstrate the practicality of a modular approach to microfluidic systems, by incorporating a range of microfluidic devices in a system integrated by means of a fluidic backplane, in this way the project aimed to provide the initial. steps towards standardisation of microfluidic devices, interfaces and integration approaches.

In addition to providing a basic interfacing technology the project also invoked the design and development of generic fluidic demonstrators. the realisation of the component parts and the illustration of their potential by characterising the resulting system performance.

The project involved the design of fluid pumps, valve, flow sensors, turbines and conductivity sensors, in addition to the passive 'fluid interconnects and required the development of the associated modelling software. In particular. the modelling required the development of a practical means of incorporating mechanical movement within a general fluid dynamics model and the validation of the fluid dynamics models for the fluid motion in microchannels. The success of this design tool was illustrated in its successful analysis of bidirectional pumping action.

Two main actuation methods, electrostatic and thermopneumatic, were successfully demonstrated in the pump designs with the electrostatic approach providing low power dissipation and fast response times while the lower efficiency thermopneumatic approach yielded a potentially more robust design. In parallel, flow sensors were developed covering a wide dynamic range by utilising complementary drift-diffusion (quasi-static) and (dynamic) time-of-flight approaches.

The project successfully showed that this approach was feasible with the partners across the project contributing components to a primary (low pressure) demonstrator which included both electronic and fluidic interfaces in the form of an electrical wiring substrate and a fluidic backplane respectively. In achieving this goal a number of difficulties had to be overcome. In particular these concerned the development of low stress joining techniques, procedures for priming of "the whole system and maximising yield m the multi-component demonstrator assemblies. In addition to this main demonstration, a secondary micro-turbine demonstrator was used to investigate the potential for microfluidic power tools in a high pressure microfluidic system. These systems aiso successfully demonstrated the use of a fluidic backplane as a particular means of interconnecting fluidic devices from different sources. The potential of this standard approach is being explored further in follow-on projects, with the aim of using such standards as a means of speeding commercialisation and enhancing competitiveness.

2. THE CONSORTIUM

This pr-eject involved the collaboration between GEC-Marconi Material; Technology Lt d (GMMT) as co-ordinating partner and Siemens, 3T BV, the Fraunhofer Institute (IFT) and Heriot-Watt University (1-I W). The primary contact points are given below, with a descript ion of the partners and their roles being provided in the following section.

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2.2 Descriptions of the Partners

The project was lead by GEC- Marconi Materials Technology Ltd., a management company for GEC-Marconi Ltd. GEC-Marconi is a major European Manufacturing company with world-wide interests in the electronic. electrical. printing and sensing fields. It is primarily a syst cm focused company, as opposed t 00 component supplier. and has identified a need for miniature. micro! abricated. integrated fluid systems as a key enabling (ethnology in a number of existing and potential business areas.
In addition to its overall co-ordinating role GMMT had particular responsibilities for bonding techniques, thermofluidic modelling and for the design, fabrication and assessment of fluidic components including act ive valves and actuators.

Siemens is among the largest European manufacturers of electron ic and electrical equipment and components. Business areas extend from prover generation to medical and analytical equipment. Involvement in the development of' methodologies and technologies for microfabricated fluid devices has had an important position in corporate strategy and has ensured exploits :ion of the results.
Within the project Siemens have taken responsibility for electrical modelling, surface wear. and micropump design, fabrication and testing.

3T BV is a small product development company (over 30 people) m the area of microelectronics and MST, working closely with Twenty University on MST and particularly on the microfabrication of miniature fluidic devices. Within the consortium it brought a wide range of existing experience m the development of microfabricated fluid devices as commercial products. In addition the resources of Twenty University were made available to the consortium through, subcontract.
Within the project 3T took particular responsibility for the design, fabrication and testing of ancillary ' sensor devices (flow sensors and conductivity sensors) and the final demonstrator design.

The Fraunhofer Institute for 'Solid State Technology (IFT) is a partly "Government funded research institute providing parallel expertise to that of 3T but with a stronger emphasis on the fundamental aspects.
The IFT took responsibility for the establishment of etching techniques within the project with a particular interest in silicon. etching (Bulk Micromachining) and the development of robust masking techniques. In addition they were responsible for the pump design and fabrication m partnership with Siemens and for the interfacing of the components developed across the consortium_

Heriot-Watt University has expertise in mechanical testing, materials assessment and modelling and provided an important academic underpinning to these aspects of the project.
Heriot-Watt took responsibility for mechanical modelling and testing the properties of materials m order to provide a basis for the choice of materials and fabrication techniques used for the component fabrication.

The consortium contributed across the whole spread of the project but with the final demonstrators being centred on GM MT and Heriot-Watt for the Microturbine and on IFT, 3T and Siemens for the Microchemical analysis system.

3. TECHNICAL DESCRIPTION

The miniaturisation of fluidic systems is expected to yield a number of technical and economic benefits. which in the case of chemical analysis systems. arise from substantially reduced sample and reagent consumption the low power operation. feasible and possibly improved performance particularly from the reduced times associated with reduced diffusion distances. In the case of fluid droplet printing systems. miniaturisation is essential in order to achieve the printing densities required. while in micro-surgery. mechanical manipulation and cutting tools realised with microfluid components could provide compact. safe. non-electrical solutions

From the viewpoint of system architecture. the microfluid systems required for these tasks form a complex arrangement of active and passive microfluid components (micropumps microvalves, mixers, etc.), micro channels and various sensors for the monitoring of chemical and physical parameters. Due to the complex nature of these systems it is obvious, that the fabrication of components and subsystems will be performed by a number of different suppliers rather than by a single enterprise. The project therefore set out to address this problem targeting the basic goals:

- to set up a design methodology for microengineered fluid devices. which could contribute as a more general interfacing standard for this class of microsystems.
- to apply this interfacing standard to relevant microfluid components (e.g. micropumps, microfluid components and sensors), and
- to build up a demonstrator system. which follows the above-mentioned design rules and shows the feasibility of the whole concept.

3.1 Modelling and Simulation

Microfluid systems consist of a lot of different components like micro channels, microvalves and pumps with a range of different actuation principles. Within the project, we used conventional FEM-programs (AN SYS-FLOTRAN and Pheonics) for the simulation and optimisation of the micro fluid systems [1]. However, because of the small lateral dimensions of these systems, these conventional tools required testing and validation.

The fluid flow through channels with circular or rectangular cross-section can be analytically calculated. But because of KOH-etching, micro channels have a trapezoid shape and the flow can not therefore be described by an analytical solution. For that reason a lot of channels with different widths and heights were simulated with ANSYS. The results have been successfully compared with measurements. From the simulation results an analytical approximation could be derived which calculates the flow through trapezoid channels with a difference less than 1 %o. In addition, good agreement was obtained between the simulation results of Ansys-Flotran on Pheonics.

For the simulation of microvalves, the coupling of mechanical and fluidmechanical model has to be considered. Because of the sensitive structure of the valves, the surrounding fluid has a basic influence to the dynamic of the system. Commercial software for Finite-Element-Method (FEM) only calculates the dynamic of mechanics and fluidmechanics as separate problems.

For that reason we developed a new simulation method. called fluid-structural-coupling [2]. Using the standard tools of ANSYS an interface was added which allows the simulation of mechanical motion inside a fluid, considering fluid pressure and fluid friction. The new software was tested with different examples and the simulation results show an excellent agreement to measurements [3].

Using this method, the coupled simulation of the dynamic behaviour of microvalves including fluid dynamics succeeded for the first lime [1]. The static flow rate through different valve geometry's could be simulated in good agreement to measurements. Further more the dynamic behaviour, like eigen frequency of the valve flap, could be calculated. The same method was used to simulate a two-dimensional model of a complete micropump including two check valves and an electrostatic drive [3]. The results contribute to the understanding of the complex processes inside the pump which cant be realised by measurements. The dynamic behaviour of the complete three-dimensional micropump was simulated by a system of differential equations which include the FEM-results by characteristic lines [1].

3.2 Materials for Microfluidics

Methods for the assessment of microengineering materials were developed as a means of predicting performance and device lifetimes as well as for design purposes. The specific measurements were aimed at selected microengineering materials such as silicon and electroplated nickel. In particular, the programme included:

- fracture strength measurements on silicon (and silicon-carbide coated silicon) cantilevers used in micropumps
- Young's modulus measurement of thin film materials
- fiction measurements of electroplated nickel cogs
- wear assessment of nickel cogs

The fracture strength of silicon cantilevers was found to increase significantly with the presence of a thin film carbide layer. Young's modulus measurements were found to correspond well with macroscopic values. Friction was found to be dependent on the normal load and to be very high for small test structures. A region of enhanced friction was found below 1 mg structure mass, below which empirical relations were developed to describe the frictional behaviour. Wear in the microcomponents tested was too small to measure using the available techniques but was found to slightly decrease the measured fiction of samples and the measured mass dependency. This suggested that surface polishing of moving components might increase "their efficiency or that there might be a run-in period for some devices (particularly for micromotors or microturbines).

3.3 Actuation Principles

The performance of miniaturised pumping systems relies largely on the characteristics of their micromechanical driving units. In order to achieve high pure] rates and low back pressure dependency, the micro actuator must feature high operating speed, sufficient displacement and produce relatively large mechanical forces.

The project considered two alternative actuation approaches, electrostatic actuators and new actuation principles and technologies based on thermopneumatic, bubble actuators.

As the driving unit for the micropump, the bubble actuator comprises two major parts. One part is the bubble generator unit made up of a thin film heater resistor with conductive lines and pads on a substrate. The other part is a silicon mid-membrane which forms the liquid filled actuation chamber and the pump chamber respectively.

The working principle of both electrostatic and thermopneumatic pumps is based on using the pressure change in a pump chamber due to periodical movement of an actuated membrane. With an increase in pressure inside the pump chamber, the outlet flap valve opens and liquid leaves the pump chambe l". When the membrane relaxes. liquid streams. due to volume enlargement and related pressure drop. into the pump chamber via the inlet valve.

In the experiments chromium silicide ($CrSi_2$) in particular was used as the heating material. Chromium silicides have excellent properties as heating material, such as high resistivity (1000μΩcm - 5000μΩcm), low thermal degradation and a temperature coeffic ent in the ppm/°C- range. The sputtered thin films were free of gross nucleation sites. Another aspect in t mums of Opel"'atiug speed is the heat-abstracting characteristic of the substrate. The amount of thermal energy dissipating over the substrate affects the dynamic behaviour of bubble formation and collapse. Good thermal insulation of the substrate during the heating phase and rapid temperature withdrawal between the pulses (cooling phase) is required. An insulating oxide layer (3 μm) on a silicon substrate of good thermal conductivity meets these requirements.

Actuators with different membranes (standard silicon. silicon Nitride, electroplated nickel and polyimide) were modelled, fabricated and tested, with both thermopneumatic and dual-phase actuation in order to investigate the possibilities for application in pumps. With respect to pressure build-up dual-phase actuation "seemed to be promising. However, the power consumption is high and practical problems can be expected. Thermopneumatic actuation in combination with a polyimide membrane was a particularly good choice, because of the relatively large pump strokes, which reduces the problems with air bubbles and priming of the pump. This was confirmed in experiments with fabricated pumps.

3.4 Microfluid Devices

For the microfluid demonstrator various microfluid devices were developed and fabricated according the predefine interfacing standard; besides various ancillary devices (e.g. fluid connectors) the development targets of this work basically comprised:

- an electrostatically actuated micro diaphragm pump developed at the IFT: this micropump basically consists of four silicon chips with outer dimensions of 7 x 7 mm^2, which are mounted as a stack **and** form an electrostatic actuation unit and a flap valve unit. Pumping operation is achieved by applying a square wave signal to the electrostatic actuator, which causes an alternate electrostatic attraction and mechanical relaxation of the flexible pump diaphragm, which forms one electrode of the actuator. With a stroke volume of about **30 nl** the actual design delivers a pump rate up to **1ml/min**. At a supply voltage of **200** V the micropump can generate a maximum counter pressures of 300 hPa at operation frequencies ranging from less than 1 Hz up to several kHz.

- a micro diaphragm pump with a chip size of about 5 x 5 mm^2 developed by Siemens, which uses a bubble actuation unit: the bubble actuation principle exploits the phase change transition in a liquid-filled cavity (actuation chamber) to exert hydrostatic pressure to a thin silicon membrane. Due to cyclic evaporation the silicon pump diaphragm is deflected and displaces the liquid inside the pump chamber. To achieve a sufficient membrane stroke and a high operating speed, the electrical drive and the appropriate thermal design of the actuator is very important. For this actuator the volume stroke was found to be larger than 30 nl. Because of the short response time, the bubble actuator can be operated with frequencies up to 1 kHz.

- a micromechanical flow sensor as a joint effort of' the MESA research institute at the University of Twente (design) and 3'1' (fabrication and demonstrator integration): this sensor chip measures **5 x 10** mm^2 and contains a flow channel that is bridged by thin membranes containing electrical resistors. Three adjacent resistor bridges are needed in this application with the middle resistor bridge being used as a heater, while the outer two serve as upstream and downstream temperature sensors. Two kinds of micromachined flow sensors were investigated. The more well known thermal anemometer anti a time-of-flight sensor. The first one is appropriate for general (low) flow and extreme dynamic measurements, because of the low thermal capacity. However, the design has to be carefully chosen regarding robustness and flow range. The time-of-flight sensor is very appropriate in specific applications. When dynamic properties and ranges are defined, a proper designed sensor measures in a broad range of' flows under the condition that the frequency of the flow fluctuations is an order lower than the measurement frequency. Beside the flow measurement a combination of both principles makes it possible to determine the composition of mixture of two compounds.

- a micromechanical conductivity sensor. developed by 3T, which uses the. same geometric design as the flow sensor: instead of resistors, the sensor employs a number of Platinum electrodes integrated into the bridging membranes.

- a silicon backplane in joint effort of IFT (design) and Siemens (fabrication): this backplane contains anisotropically etched flow channels to connect all microfluid devices. The microchannels are sealed with a Pyrex cover by anodic bonding. in the backplane design the micropumps were placed as a compact unit surrounded by some spare place to allow the integration of an electrically shielding cover if required.

- valves to control and switch flow were developed. These consisted of passive check valves fabricated in silicon by IFT and active electroformed nickel valves developed by GMMT where the switching was achieved using thermopneumatic actuators.

- fluid turbines were designed by Heriot-Watt University and fabricated by GMMT using an electroplating process 'on a variety of substrates including metal (Aluminium) and glass. The electroplating process provided the fluid channels and the use of a sacrificial layer beneath the plating allowed the moving rotors to be released from the substrates.

3.5 Demonstrators

Demonstrators were designed and fabricated to show clearly the possibilities of a micro fluidic system consisting' of device components in a modular set-up as a practical approach to the" development, fabrication and evaluation of fictional prototypes. It should be noted that for commercial products the integration and interfacing techniques will need to be developed further. In particular, great attention will need to be paid to the attachment of components on the backplane and the fabrication of the backplane it self. The backplane used in the demonstrator consisted of a silicon wafer and a Pyrex wafer and would probably be too expensive for higher 'volume applications.

Interfacing Standards for Microengineered Fluid Devices

Within this modular approach the primary consideration was the early definition of the interfacing approach and the required device compatibilities. The following relevant topics for an interfacing standard were identified and addressed:

- the lateral dimensions of the individual devices
- the position of the fluid ports on the individual devices
- the electrical connections of the devices
- mounting technologies for the individual devices on the backplane.
- the priming of the system,
- particle control. and

• the connection to the outside world.

Following this list, standards and design rules were set within the project consortium and applied for the realisation of silicon micromachined microfluid components and, finally, a microfluid demonstrator. Although this may not be not apparent on the first sight, the problem of interfacing microfluid components turned out to be a complex endeavour, which is not only influenced by technical requirements but also by economic implications. To give only one example: concerning the lateral dimensions of silicon microfluid devices, a common chip size for a specific group of devices would be the "simplest" way and substantially ease interfacing and exchangeability. At the current state of the art, however, this is economically and technically not feasible in many cases. The chip sizes of already existing microfluid devices vary considerably (e.g. between 5 x 5 mm² and 22 x 22 mm² for micropumps). Making a micro fluid device unnecessary large to adhere to a predefine standard will increase the fabrication costs dramatically. Therefore, in this situation it is only useful to apply a standardised grid to all relevant dimensions, which means, that the chip sizes and the placement of fluid ports could be performed, for instance, in a multiple of 500 pm.

3.5.1 Case Study: A Microanalyser for Conductivity Measurements

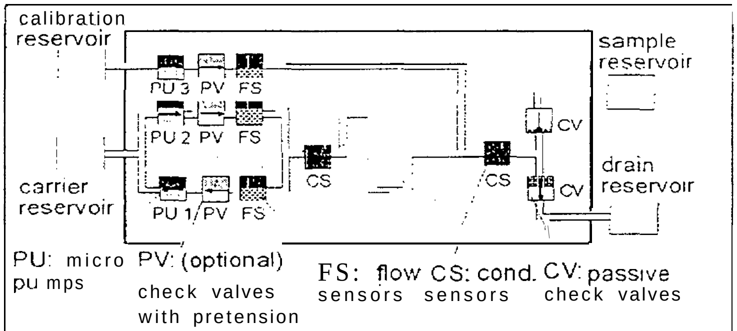

Figure 1. **Schematic diagram of the chemical analysis microfluidic system demonstrator.**

Fig. 1 shows a schematic diagram of the microfluid system demonstrator, which was designed as a chemical analysis system. The system contains three pumps, three corresponding flow sensors to control the individual pump rates, two conductivity sensors and two passive check valves.

During analysis the individual micropumps perform the sample uptake (PU I), a defined cleaning of the system (PU 2) and an optional sensor calibration (PU 3), respectively. The flow rate of the individual pumps is controlled via the corresponding flow sensors. At the end of an analysis, the sample is transported to a waste reservoir through a separate microchannel, which is opened by applying hydrostatic overpressure to the passive check valves (CV) mounted at the sample and waste port. To avoid unwanted parasitic leakages through the unoperated micropumps, passive check valves (PV) with a defined opening threshold pressure were developed by the IFT to be mounted between the micropumps and the flow sensors.

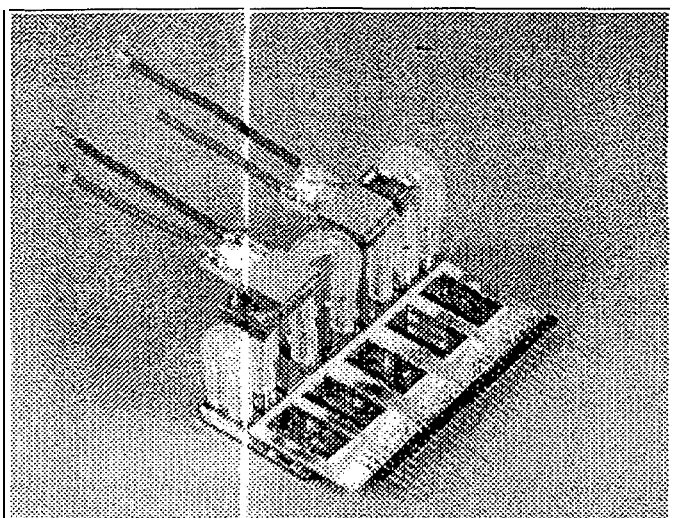

Figure 2. The assembled demonstrator system.

For the electrical connection of the flow and conductivity sensors a ceramic substrate with screen-printed conductors and bonding pads was fabricated by the IFT. The system was assembled by gluing the ceramic substrate and the sensors onto the backplane. The sensors were electrically connect cd to the ceramic substrate by standard wire bonding. For all exchangeable parts and all external fluid connections appropriate push-on fluid connectors were developed. Fig. 2 shows the assembled demonstrator.

Measurement *Results*

Meanwhile. initial conduct ivit v measurements have been carried out to .demonstrate the operat ion oft he micro fluid system. Fig. 3 shows the result of a typical measurement. which comprises of a sampling step. a short phase with stopped flow and a cleaning step before the next cycle is initiated. As the sample gets into contact with the conductivity sensor a corresponding decrease of the sensor signal" occurs, which reaches its extreme value at the end of the sampling phase. During the cleaning step, where the sensor signal returns to its baseline level, dispersion of the liquid can be observed as well as a parasitic peak generated by the sharp turnover' from micropump 2 to micropump 1 at the beginning of the next sample cycle.

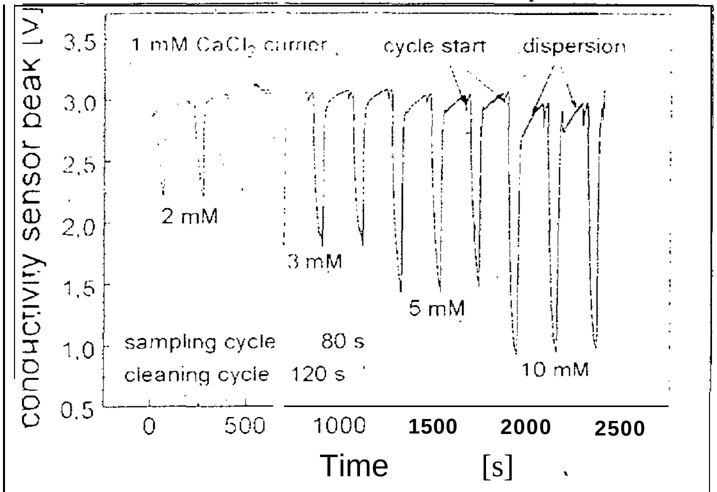

Figure 3. Typical conductivity measurement cycles on a range of sample solutions, interspersed with cleaning phases.

3.5.2 Case Study: Microfuidic Turbine

An ancillary fluid system based on demonstrating a microturbine actuator was developed in the final phase of the project and was used to demonstrate the potential for high pressure microfluid "power" devices, with a possible application in micro surgery.. Liquid flow investigation! is were carried out in electroplated microchannels 63 and 27µm deep at higher supply pressures than for the main demonstrator. Macroscopic models were found to adequately describe the behaviour of liquids at this scale. A test mask was also designed to investigate the fictional design features of the microturbines. From these design results and the empirical micromechanical properties, design rules for microactuators were accumulated. A final design was proposed as part of an auxiliary demonstrator system comprising a microturbine actuator, a UV-LIGA backplane and provision for an active valve as controlling mechanism.

The demonstrator was dynamically tested using a viscous braking technique. The results showed that the units produced maximum torques in the region of 1.2 micro Newton metres under 0.75 bar nitrogen drive. The devices were found to be very sensitive to loading with small shaft loads causing large changes in rotor speed. The dynamic results for' the turbine suggested that significant improvement in load characteristics could be attained for devices with higher aspect ratios (i.e. taller structures). In summary, the programme has shown that there is significant potential for this type of fluid microsystem with some of the first dynamic tests on fluid actuators.

3.6 Summary

Within this project it has been shown, that it is possible to integrate different microfluid devices fabricated by various European suppliers to form a complex microfluid system. To solve the problem of interfacing, a proposal for an interfacing standard of microfluidic devices was set and applied for the realisation of a working demonstrator system. Due to the large variety of technologies applied for microfluid systems today, the aspect of standardisation has turned out to be a quite complex task already within this project. It is evident, that a more widespread standardisation is not achievable within a short time, nevertheless this topic should to be further addressed to optimise the benefit obtainable from the widespread on-going research in the field of microfluidic systems. Such standard interfaces will both speed the commercial evaluation of this promising technology and provide a strong competitive advantage in the subsequent exploitation.

4. EXPLOITATION PLAN

Exploit ation of the results of' this programme is taking two forms. ly. the d emonstrator devices and the developed microfluidics methodologies are themselves being c irect ly exploited. Secondly. the underlying techniques and fabrication tools are being exploited in parallel microfabrication applications. The project involved a primary chemical ana lysis demonst rat or anc a secondary high speed turbine demonstrat or. While the latter requires further development before .t could be exploited. the primary demonstrator is being directly marketed as a technology demonstrator.

4.1 Miniaturised Chemical Analysis System

Although some further development of the chemical analysis demonstr ator system will be required before it is qualified as an analytic tool, the basic system is sufficiently matu e to be marketed as a technology demonstrator. Marketing of the micropump components by the Fra nhofer Institute (1 FT) has already started on the basis of an evaluation kit containing a number of micro pumps. a driving electronics and a training course. This has been sold to various interested companies anc institutes in Europe and the USA.

in addition, the basic chemical analysis concept is being further markete d and 'customer tested' m the form of a miniaturised HPCE chemical analysis system for a space application. This further. close to market development is to be undertaken with support from ESA in a collabor ation involving 3T and Dutch and Swiss partners.

4.2 Microturbine

The results from the auxiliary demonstrator design have shown that microfluid devices could be used as mechanical actuation units. Such units have significant application potential in many areas including microsurgical tools and microactuation control of miniature robotic units. These devices will require significant further development before exploitation.

The exploitation route for this aspect of the technology therefore requires further development" m which the key areas of fiction reduction on the microscale, and improving the dynamic load characteristics are addressed. This further, research and development by Heriot Watt University will focus on identifying both manufacturing and end user partners for integrated development. programmed, with support being sought from national and European programmed and from partners themselves.

4.3 Microfluidics Expertise

Future exploitation of the microfluidics expertise will involve a wide range of application areas. In .pat-titular, this will involve the application of deep etching technology (by 3T) and electroforming technology (by GEC) for inkjet nozzles. These parallel nozzle developments are being pursued within commercially-funded projects for relatively low-risk development of inkjet printing systems.

GEC is now also taking a lead role within the ESPRIT (Framework four) EUROPRACTICE project. This collaborative programme aims to encourage the take-up Of technology development more widely across Europe by supporting the setting up of a network of manufacturing capabilities with the area of Microsystems in particular. The fluidics expertise developed in this project will be made available to European industry through this EUROPRACTICE project.

Publications by the non-industrial partners will also be used to provide wide-spread information concerning the state-of-the-art achieved and the advantages of'the new technology.

4.4 Spin-off Exploitation

The techniques and skills developed within the Brite-Euram programme are being utilised in a range of other development programmes within all the partner organisations. In addition to the basic Bulk Micromachining and Electroforming fabrication techniques which will be exploited in a variety of new microsystem developments, some of the structures and components are also exploitable in non-fluidic applications. In particular, both Siemens and GEC will be exploiting the membrane technologies developed in this programme, in Microrelays and in thermal isolation bridges for Thermal Imaging Devices respectively

The Silicon Carbide process developed within the framework of this project is meanwhile used at the IFT as a standard process for micromechanical silicon structuring. Releases of publications concerning the subject are already in progress.

4.s **Standardisation**

In addition to the specific device exploitation opportunities identified within the project, the successful demonstration of the modular approach to fluidic system integration provides a particular advantage m the exploitation of microfluidic systems in general. The use of a standard fluidic interface approach, common to a range of different devices, will enable complete systems to be developed by the parallel activities of a number of different manufacturers. In addition, the early identification of a practical interface standard provides such first technology developers with a distinct competitive advantage over rival approaches.

For these benefits to be realised it is necessary to obtain recognition of such standards. At the end of the project, two specific routes to obtaining this recognition were being explored. Firstly, within the Esprit ‘Europractice’ project (21101), microsystems standards and standardisation requirements are being identified and recognition of the importance of such standards is being sought from standards bodies (for example, IEC). Secondly, within the ‘Modular Microanalysis Systems’ (MAS), Brite Euram Thematic Network (BRPR-ct96-00 10), standardisation is being pursued as one of the four working group activities of this project. This working group is being co-ordinated by Dr R Zengerle, a primary participant in this project, who is currently with the Hahn-Schikard-Institute (IMIT).

5. COLLABORATION SOUGHT

Heriot-Watt University is currently seeking partners to help develop micro-actuators for medical applications, including modifications of the auxiliary demonstrator turbine developed in the project. In this case the key areas for improvement which have been outlined an: those of reduction of fiction on the microscale and improving the dynamic load charact mist ics of the prototype systems. Additionally, HWU is interested in further applications of the generic area investigated in the project and in developing this into micro-chemical engineering.

Heriot-Watt is also interested in developing the more generic aspects of the technology from this project. In fluid handling systems there is considerable interest in the capacity of Microsystems for chemical and biochemical process intensification and work is going on at Heriot-Watt in artificial organ manufacture using Microsystems. Discussions are also in progress with chemicals manufacturers who are interested in chemical process miniaturisation. Nationally funded work has also recently commenced in heat exchangers incorporating micro-channels. On a more general scale, it is believed that the project methodology (of modularisation of n Microsystems using a component and channel approach) can be used in other areas. such as micro-optics and partners are currently being sought to develop this.

Future research and development will focus on identifying both manufacturing and end user partners for integrated development programmed, with support being sought from national and European programmed or from partners themselves.

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7. KEYWORDS

Microfluidics
Thermopneumatic actuators
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